EA Engineering, Science, and Technology, Inc., PBC

405 S. Highway 121, Building C, Suite 100
Lewisville, Texas 75067
Telephone: 972-315-3922
Fax: 972-315-5181
www.eaest.com

TECHNICAL MEMORANDUM

TO: Katrina Higgins-Coltrain, EPA Task Order Monitor

FROM: Pat Appel, EA Project Manager

DATE: April 16, 2020

SUBJECT: Remedial Investigation Summary, RAOs, ARARs, and Proposed Remedial Alternatives In Preparation of FS Scoping Meeting for Wilcox Oil Company Superfund Site, Bristow, Creek County, Oklahoma

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This technical memorandum (TM) addresses the email request from the EPA Task Order Manager dated 23 March 2020 in preparation of a feasibility study scoping meeting. As background information, below shows a portion of the EPA email that describes the requested tasks to be completed by EA.

"Feasibility Study Scoping

The second Management Review meeting in an NPL site's lifecycle should take place at the Feasibility Study (FS) scoping of alternatives stage. Once an RI has progressed sufficiently (including sufficient progress on human health and ecological risk assessments), the RPM and Project Team should seek management input on the range of alternatives to be considered in the FS. Prior to such a meeting, it is assumed that the following tasks would have been completed:

1. *Drafts of sufficient portions of the RI, Human Health Risk Assessment, and Ecological Risk Assessment.*
2. *Development of Remedial Action Objectives (RAOs) based on the findings of the RI and Risk Assessments, and/or Applicable or Relevant and Appropriate Requirements (ARARs).*
3. *A preliminary listing of ARARs, including ARARs provided by the state per 40 CFR 300.515(d).*
4. *A draft list of alternatives for initial screening reviewed by the RPM and appropriate Project Team members sufficient that recommendations can be made on the range of alternatives to carry forward for detailed analysis in the FS. For sites that are especially complex, the RPM may provide a full range of alternatives and suggest/solicit input on screening.*

1.0 Drafts of Sufficient Portions of the RI, Human Health Risk Assessment and Ecological Risk Assessment

This task has been addressed by the recent submitted Remedial Investigation (RI) Report.

2.1 Development of Remedial Action Objectives (RAOs) based on the Finding of the RI and Risk Assessments, and ARARs

Based on the findings of the RI and risk assessment results, following RAOs are proposed.

Soil

- Prevent human exposure to the soils with concentrations of contaminants of concerns (COCs) exceeding the preliminary remediation goals (PRGs)
- Minimize migration of soil contaminants into the groundwater, surface water, and other site soils

Groundwater

- Prevent or minimize contamination source migration and contribution to the groundwater contamination
- Prevent migration of groundwater contaminants to the surface water
- Prevent current and future use of the perched groundwater with concentrations of COCs exceeding groundwater PRGs.

2.2 Proposed Preliminary Remediation Goals

Proposed PRGs were developed based on human health risk based calculation, ecological risk based calculation, and existing EPA drinking water regulations or Maximum Concentration Levels (MCL) for groundwater. Attachments 1 and 2 detail calculation for ecological and human health risk based PRGs, respectively.

Following tables shows the calculated PRGs for soil and groundwater under residential and industrial / commercial (I/C) land use. Proposed PRGs are indicated as bold.

Soil

COC	PRGs (mg/kg)	Land Use and Source
Benzo(a)pyrene	**3**	Residential & Industrial / commercial - human health risk based calculation
Copper	**285**	Ecological risk based calculation
Lead	**400**	Residential - human health risk based calculation
	800	Industrial / commercial - human health risk based calculation
	204	Ecological risk based calculation
Manganese	**505**	Ecological risk based calculation
Vanadium	**66**	Ecological risk based calculation
Zinc	**120**	Ecological risk based calculation
Note: Mg/kg = milligram per kilogram		

Groundwater

COC	PRGs (mg/L)	Land Use and Source
Arsenic	**0.01**	MCL
	0.0005	Residential - human health risk based calculation
	0.002	Industrial / commercial - human health risk based calculation
Naphthalene	**0.0017**	Residential - human health risk based calculation
	0.15	Industrial / commercial - human health risk based calculation
Benzene	**0.005**	MCL
	0.0046	Residential - human health risk based calculation
	0.04	Industrial / commercial - human health risk based calculation
1.2-Dichloroethane	**0.005**	MCL
	0.0017	Residential - human health risk based calculation
Ethylbenzene	**0.7**	EPA drinking water regulation
	0.015	Residential - human health risk based calculation
Note: MCL = Maximum concentration level mg/L = milligram per liter		

3.0 Preliminary Applicable Relevant and Appropriate Requirements (ARARs)

Table 1 presents the ARARs, which will be revised when the PRGs and alternatives are finalized.

4.1 Technology Screening

Applicable technologies have been identified and screened using three criteria per the EPA guidance. The three criteria include effectiveness, implementability and cost. Tables 2 and 3 present the screening processes for potential soil and groundwater technologies, respectively.

Effectiveness is a measure of a technology's ability to reduce toxicity, volume or mobility of the contaminants to meet the site PRGs. Technologies that do not provide adequate protection of human health and environment or are not reliable (i.e., performance of technology is not consistent to maintain a required treatment standard) are screened out for further consideration.

Implementation is a measure of both technical and administrative feasibility of implementing a technology process. Aspects of the implementability may include workability of the technology under site conditions, availability of special equipment, materials, and skilled workers required, and complexity of the technology. Technologies that are unworkable under the site conditions, or pose considerable challenges due to complicated technical process during the construction are eliminated for further consideration.

Cost is a measure of resources that are required in technology implementation. Cost evaluation at the technology screening phase is relative, typically presented as high, low, or medium compared to other technologies within the same technology type. The technologies with high cost but low protection of human health and environment are not considered for further evaluation.

The technologies retained for further evaluation include following:

Soil:

- No further action (NFA)
- Institutional controls (ICs)
- Excavation and offsite disposal
- Excavation and onsite disposal

Groundwater:

- NFA
- ICs
- MNA
- *In situ* biological treatment

5.1 Draft Remedial Alternatives

The technologies retained from the screening process are assembled to develop a range of alternatives in order to provide some flexibility in selecting preferred alternatives. Following presents proposed alternatives for soil and groundwater.

5.2 Soil

Alternative S-1: No Further Action (NFA)

Alternative S-1 assumes no remedial action for soil to be conducted. It is considered as a baseline for comparison to other remedial alternatives. Under this alternative, the contaminated soil would be left in place and poses unacceptable risk to human health and ecological receptors.

Alternative S-2: Excavation and Offsite Disposal

Alternative S-2 includes excavation of soil exceeding the PRGs and disposal of the material offsite in a Resource Conservation and Recovery Act (RCRA) permitted and licensed landfill.

The main components of Alternative S-2 include:

- Pre-excavation delineation of contaminated soil exceeding the PRGs
- Excavation of the contaminated soil
- Transportation to and disposal of the excavated material at an offsite disposal facility
- Backfill and restoration of excavated areas
- Implementation of institutional controls to restrict the land use to either residential or industrial / commercial only (pending EPA determination of the future land use)

Alternative S-3: Excavation and Disposal at Onsite Containment respository

Alternative S-3 includes excavating the contaminated soil, and consolidating the excavated soil into an onsite containment cell.

The main components of Alternative S-3 include:

- Pre-excavation delineation of contaminated soil exceeding the PRGs
- Excavation of the contaminated soil
- Installation of an onsite containment cell, which may include:
    - Bottom liner system including (from bottom to up) an impermeable layer, a leachate collection layer and a protective layer
    - Contaminated and excavated soil
    - Capping including (from the bottom to up) an impermeable layer, a composite drainage net (for infiltration collection), and a soil cover with vegetation
- Backfill and restoration of the excavated areas

- Implementation of institutional controls to restrict the land use to either residential or industrial / commercial only (pending EPA determination of the future land use); and prohibit any drilling and earth moving activities at the containment cell.

5.3 Groundwater

Alternative GW-1: NFA

Alternative GW-1 assumes no remedial action for the site groundwater. This alternative is considered as a baseline for comparison to other alternatives.

Alternative GW-2: Monitored Natural Attenuation (MNA)

Alternative GW-2 will mainly include MNA with institutional controls to restrict groundwater use at the site. Hexavalent chromium may be reduced to the less toxic trivalent chromium by Main components of Alternative GW-2 include:

- A study to evaluate the potential of MNA as a viable remedy at the site
- MNA monitoring quarterly and evaluation of MNA effectiveness annually
- Implementation of institutional controls to restrict groundwater use at the site.

Alternative GW-3: *In Situ* Bioremediation

Alternative GW-3 consists of injection of substrate containing nutrients (i.e., nitrate) and electron acceptors to enhance aerobic biodegradation of BTEX and naphthalene. During the process, iron and manganese oxides can be generated, which would promote arsenic precipitation.

Main components of Alternative GW-3 include:

- Injection and performance observation well installation
- Injection of substrate
- Monitoring of the bioremediation performance
- Reinjection if needed
- Implementation of institutional controls to restrict groundwater use at the site.

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Tables

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Table 1. Potentially Applicable or Relevant and Appropriate Requirements

ARARs/TBCs	Citation or Reference	Requirements	Applicability
Chemical-Specific ARARs			
National Primary Drinking Water Standards	40 Code of Federal Regulations (CFR) Part 141	Establishes health-based standards (i.e., MCLs) for public drinking water.	Applicable for contaminants, which affect groundwater.
Clean Water Act	40 CFR Part 122	The National Pollutant Discharge Elimination System (NPDES) program is the national program for issuing, monitoring, and enforcing permits for direct discharges. 40 CFR Part 122 requires permits for the discharge of "pollutants" from any "point source" into "waters of the United States.".	Applicable potentially for alternatives of groundwater treatment system. Under the Superfund Program, an onsite discharge from a CERCLA site to surface water must meet the substantive NPDES requirements, but need not obtain an NPDES permit or comply with the administrative requirements of the permitting process.
Oklahoma Water Quality Standards	Oklahoma Administrative Code (OAC) 785:45	Establishes uses of waters of the state, criteria to maintain and protect such classifications and other standards or policies pertaining to the quality of such waters. These standards include groundwater protection requirements.	The requirements are applicable to the discharge of water from groundwater treatment if a treatment system is included in remedial alternatives.
Implementation of Oklahoma Water Quality Standards	OAC 785:46	Establishes rules to implement the Oklahoma Water Quality Standards established under OAC 785:45.	May be applicable if remedy requires a surface water discharge.
Designation of Hazardous Substances, Determination of Reportable Quantities	40 CFR 302.4 – 302.5	This section provides tables on the following substances: a). Listed hazardous substances. The elements, compounds, and hazardous wastes appearing in Table 302.4 are designated as hazardous substances under Section 102(a) of CERCLA. b). Unlisted hazardous substances. A solid waste, as defined in 40 CFR 261.2, which is not excluded from regulation as a hazardous waste under 40 CFR 261.4(b), is a hazardous substance under Section 101(14) of CERCLA if it exhibits any of the characteristics identified in 40 CFR 261.20 through 261.24.	Applicable because hazardous substances might be in the contaminated soil, and groundwater. Waste encountered during the remediation of the contaminated media will be characterized to determine whether it is hazardous or nonhazardous.

ARARs/TBCs	Citation or Reference	Requirements	Applicability
Identification and Listing of Hazardous Waste	40 CFR 261	Identifies those waste subject to regulation as hazardous wastes.	The criteria and limitations used to identify wastes as being hazardous or nonhazardous are applicable to all wastes transported offsite and are relevant and appropriate to all alternatives at the site.
Oklahoma Air Pollution Control Rules	OAC 252:100	Establishes controls for specific hazardous air pollutants.	Applicable to discharge of fugitive dust during remedial actions.
Airborne Contamination Monitoring	American Conference of Governmental Industrial Hygienists – Threshold Limit Values (TLV)	Based on the development of a time-weighted average exposure to an airborne contaminant over an 8-hour workday or a 40-hour workweek, TLVs identify levels of airborne contaminants at which health risks may be associated.	Applicable during implementation of alternatives.
Airborne Contamination Monitoring	American Conference of Governmental Industrial Hygienists – Estimated Limit Values (ELV)	ELVs provide some indication of airborne contaminant levels at which adverse health effects could occur.	Applicable during implementation of alternatives.
OSHA Worker Protection	29 CFR 1910, 1926 and 1904	Establishes requirements for occupational health and safety applicable to workers engaged in hazardous waste site or CERCLA response actions	Applicable during implementation of alternatives.
Location-Specific ARARs/TBCs			
Floodplain Management	Executive Order 11988	Establishes federal policy and guidance for activities completed in floodplains	To be considered (TBC) since portions of the site are within a 100-year floodplain.
Protection of Wetlands	Executive Order No. 11990	Mandates that Federal agencies and potentially responsible parties avoid, to the extent possible, the adverse impacts associated with the destruction or loss of wetlands and avoid support of new construction in wetlands if a practicable alternative exists.	TBC during remedial actions since portions of the site are within or near wetlands.
Substantive requirements of Nationwide Permit #38 – Cleanup of Hazardous and Toxic Waste	33 CFR 330	Requires assessment of remedial actions to determine that impacts to wetlands cannot be avoided. Includes substantive performance standards. If mitigation is required a plan must be prepared and implemented. No pre-construction notification is required for CERCLA actions.	Applicable if remediation affects navigable waters or wetlands.

ARARs/TBCs	Citation or Reference	Requirements	Applicability
Migratory Bird Treaty Act	16 United States Code (USC) 703	Protects almost all species of native birds in the United States from unregulated taking.	Applicable if work is taking place in a migratory flyway.
Endangered Species Act of 1973	16 USC 1531-1548; 50 CFR Part 17 and 402	Requires remedial agency to consult with Fish and Wildlife Service if action may affect endangered species or critical habitat. Requires action to conserve endangered species within critical habitats upon which endangered species depend, includes consultation with Department of Interior.	No documentation is found to show endangered species are present at the site, however, it is TBC to confirm that during the soil remediation.
Permits and Enforcement	CERCLA 121 (e)	This section of CERCLA states that no "federal, state, or local permit" shall be required for any portion of a CERCLA remedial action that is conducted on the site of the facility being remediated. This includes exemption from the Resource Conservation and Recovery Act (RCRA) permitting process. Note that the substantive requirements of the regulations must still be met (e.g., construction stormwater must be managed using best management practices [BMPs]).	Applicable to the remedial action at the site.
The Native American Graves Protection And Repatriation Act	25 USC Section 3001 et seq and its regulations Title 43 CFR Part 10	Protects Native American graves from desecration through the removal and trafficking of human remains and cultural items including funerary and sacred objects.	Substantive requirements applicable if Native American burials or cultural items are identified within area to be disturbed.
National Historic Preservation Act	16 USC 470 et seq; 36 CFR Part 800	Provides for the protection of sites with historic places and structures	Substantive requirements applicable if eligible resources are identified within area to be disturbed.
Archeological Resources Protection Act of 1979	16 USC Sections 47000-47011; 43 CFR Part 7	Prohibits removal of or damage to archaeological resources unless by permit or exception	Substantive requirements applicable if eligible resources are identified within area to be disturbed.
American Indian Religious Freedom Act	42 USC Section 1996 et seq.	Protects religious, ceremonial, and burial sites, and the free practice of religions by Native American groups.	Substantive requirements applicable if Native American sacred sites are identified within area to be disturbed.

ARARs/TBCs	Citation or Reference	Requirements	Applicability
ACTION-SPECIFIC ARARs/TBCs			
Water Quality Standards	40 CFR 131	States are granted enforcement jurisdiction over direct discharges and may adopt reasonable standards to protect or enhance the uses and qualities of surface water bodies in the state.	Applicable to direct discharge of treatment system effluent or other process waters.
Hazardous Substances	40 CFR A Parts 116.3 and 116.4	Establishes reporting requirements for certain discharges or reportable quantities of hazardous substances. Creates no substantive clean up requirement.	May be applicable to the site based on the chosen remedial alternative and if discharges of reportable quantities of hazardous substances occur during implementation of the remedy.
Underground Injection Control	40 CFR. Part 144 OAC 252:650 and 652	Injection of liquids associated with remedial alternatives is subject to Federal and State Underground Injection Code (UIC) requirements.	Applicable for groundwater treatment alternatives involving injections. Operators of Class V injection wells must notify the UIC Director and submit inventory information about the well. Class V injection wells cannot allow the movement of fluid into underground sources of drinking water that may cause the violation of primary drinking water standards or health based standards. Class V injection wells must be closed in accordance with 40 CFR. 144.82(b)
RCRA	40 CFR. Part 262 Subsection B, & Part 263, 49 CFR 100 through 199	Establishes responsibilities for transporters of hazardous waste in handling, transportation, and management of the waste. Sets requirements for manifesting, recordkeeping, packing, labeling, and emergency response action in case of a spill.	Applicable depending on waste classification and if it is transported offsite for disposal.

ARARs/TBCs	Citation or Reference	Requirements	Applicability
RCRA Land Disposal	40 CFR Part 268	Land Disposal Restrictions (LDRs): Establishes restrictions on land disposal unless treatment standards are met or a "no migration exemption" is granted. LDRs establish prohibitions, treatment standards, and storage limitations before disposal for certain wastes as set forth in Subparts C and D. Treatment standards are expressed either as concentration based performance standards or as specific treatment methods. Wastes must be treated according to the appropriate standard before wastes or the treatment residuals of wastes may be disposed in or on the land. The Universal Treatment Standards establish a concentration limit for 300 regulated constituents in soil regardless of waste type.	Applicable for disposal of hazardous wastes
Transportation	49 CFR. Part 171	Hazardous materials that may be transported off site cannot be transported in interstate and intrastate commerce, except in accordance with the requirements of 49 CFR Part 171, Subpart C.	Applicable. Any offsite transportation of hazardous waste will comply with these regulations, which contain packaging, placarding, labeling, and other shipping requirements.
National Primary and Secondary Ambient Air Quality Standards	40 CFR 50 and Clean Air Act Part A, 109	Establishes ambient air quality standards.	Applicable to alternatives that potentially generate emissions, i.e., stabilization, *in situ* injection, and waste removal.
Requirements for Preparation, Adoption, and Submittal of Implementation Plans	40 CFR 51	Requires excavation activities be controlled to minimize fugitive dust emissions.	Applicable to some alternatives that will generate fugitive dust emissions from excavation of contaminated soil.
Clear Water Act	Title II, Section 208(b)	The proposed action must be consistent with regional water quality management plans as developed under Section 208 of Clean Water Act.	Substantive requirements adopted by the state pursuant to Section 208 of the Clean Water Act would be applicable to direct discharge of treatment system effluent or other discharges to surface water.
Clear Water Act	Title III, Section 304	Establishes water quality criteria for specific pollutants for the protection of human health and for the protection of aquatic life. These federal water quality criteria are nonenforceable guidelines used by the state to set water quality standards for surface water.	Water quality criteria may be relevant and appropriate to groundwater or other discharges to surface water.

ARARs/TBCs	Citation or Reference	Requirements	Applicability
Effluent Guidelines and Standards	40 CFR 400 series	Wastewaters from certain processes need to meet certain pretreatment requirements and concentrations before being discharged to a publicly owned treatment plant (POTW) or discharged through a permitted outfall. These standards include: - 40 CFR 437 – Centralized Waste Treatment Point Source Category - 40 CFR 445 – Landfills Point Source Category	Applicable, if a waste liquid is produced and treated during remediation prior to discharge or relevant and appropriate if groundwater is treated and discharged.
Guidelines for Land Disposal of Solid Wastes	40 CFR 241	Offsite solid waste land-disposal units must meet the federal guidelines for the land disposal of solid wastes.	Applicability depends on waste classification for wastes generated from the remediation.
Criteria for Classification of Solid Waste Disposal Facility and Practices	Subtitle D, 40 CFR 257	Sets standards for land disposal facilities for nonhazardous waste.	Applicable to transport and disposal of any nonhazardous waste offsite.
Hazardous Waste Management; Standards Applicable to Generators of Hazardous Waste; and Standards Applicable to Transporters of Hazardous Waste	Subtitle C 40 CFR 260, 262, and 263. OAC 252:205 – Oklahoma Hazardous Waste Management Rules	Regulates the generation, transport, storage, treatment, and disposal of hazardous wastes generated in the course of a remedial action. Regulates the construction, design, monitoring, operation, and closure of hazardous waste facilities.	Requirements under these regulations may be relevant and appropriate to storage of wastes or treatment system residuals.
Solid Waste Management	OAC 252:515	Implements the Oklahoma Solid Waste Management Act (OSWMA), which provides rules for the transportation, handling, storage, and/or disposal of solid waste regulated by the OSWMA.	The requirements are applicable to the transportation, handling, storage, and/or disposal of any solid wastes generated during remedial action.
General Water Quality Standards	OAC 252:611	Nonpoint source Pollution controls	Substantive requirements are relevant and appropriate to construction activities.
Well Driller and Pump Installer Licensing	OAC 785:35	Establishes requirements for well drilling and plugging.	Potentially applicable if installation or plugging and abandonment of groundwater monitoring wells or boreholes takes place.

ARARs/TBCs	Citation or Reference	Requirements	Applicability
Notes: ARAR = Applicable Relevant and Appropriate Requirement BMP = best management practice CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act CFR = Code of Federal Regulations ELV = Estimated Limit Values LDR = Land Disposal Restrictions MCL = Maximum Concentration Level NPDES = The National Pollutant Discharge Elimination System OAC = Oklahoma Administrative Cod OSWMA = Oklahoma Solid Waste Management Act POTW = Publicly owned treatment plant RCRA = Resource Conservation and Recovery Act TBC = To be considered TLV = Threshold Limit Values UIC = Underground Injection Code USC = United States Code			

Table 2. General Response Actions and Potential Applicable Technologies - Soil

General Response Action	Remedial Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Potential for Retain for Further Evaluation
No Further Action	None	None	No further action to address contaminated soil and sediment.	Will not address the remedial objectives.	None	None	Yes as baseline for evaluation process
Institutional Controls	Access and Use Restrictions	Land Use Controls	Land use restriction (i.e., deed notice or restrictive covenant) is issued for properties located in the contaminated areas to restrict the land use to either residential or industrial / commercial only pending on EPA decision.	Will prevent direct exposure to the contaminants; therefore it will address relevant remedial objectives.	Implementable	Low	Yes
Containment	Consolidation and Capping	Clay Cap, Synthetic Membrane, or Chemical Sealant or Stabilizer	A cap is installed to cover the contaminated area to prevent direct exposure to the contamination. Different materials can be used for the cap and typical materials include clay, synthetic membranes, and chemical sealants or stabilizers. Contaminated soil can be consolidated in one area and capped.	Will prevent direct contact and exposure to the contaminated soil , although it does not remove the source of the contamination. It will address the relevant remedial objectives.	Implementable with commercially available equipment; potential worker and community exposure to dust; administrative controls will be required.	Medium	Not as a stand-alone technology and it is included in containment cell option
Removal	Excavation and Disposal	Excavation and Onsite Disposal	Contaminated soil is excavated and placed in a containment cell which may consist of a bottom liner and a cap. Bottom liner may consist of, from bottom to top a impermeable liner, leach collection layer, a protection layer overlain by excavated contaminated soil. A cap may consist of an impermeable layer, an infiltration collection layer, and soil cover and vegetation.	Will prevent direct contact and exposure to the contaminated soil , and contain the contaminated materials in a cell. It will address the relevant remedial objectives.	Implementable with commercially available equipment. Potential worker and community exposure to dust during the construction, therefore dust controls will be required. A deed notice is required to control the future land use and protect the integrity of the cell.	Medium, but the quantity of the contaminated soil is relatively low, so building a small containment cell might not be cost effective because of a low ratio of waste quantity versus cell construction materials.	Yes
		Excavation and Offsite Disposal	Contaminated soil are excavated and transported to a permitted offsite facility for disposal.	Will remove the contaminated soil from the site. It will address the relevant remedial objectives.	Implementable	Medium	Yes
Treatment	*Ex situ* Physical, Chemical Treatment	Excavation and Chemical Oxidation	Oxidizing agents (Fenton's reagent, permanganate, ozone, and hypochlorites) are added into the excavated soil to promote abiotic destruction of contaminants. Treated soil is placed back to the excavations.	Chemical oxidation will destroy the contaminants to become less toxic; however some metals (chromium) may become mobile once being oxidized and may impact the groundwater.	Implementable, and a bench scale testing is required to determine oxidant dosage.	High. Can be cost prohibitive if the soil contains high organic matter.	No, due to potential mobilization of metals to the groundwater
		Excavation and Soil Mixing and Stabilization/Solidification	Reagents are mixed with excavated soil by a mechanical mixing device to trap, treat, or immobilize contaminants. Treated soil is placed back to the excavations and covered by clean soil and vegetation. Reagents may include cement, bentonite, activated carbon.	Will stabilize and reduce contaminants' migration. However the treated soil is required to be protected from excavation, drilling, and other earthmoving activities. Institutional controls are required to protect the treated soil.	Implementable with commercially available equipment; treatability study is required to determine reagent dosing; may take longer time to treat; potential worker exposure is present during construction, especially during materials handling.	High	No, due to high cost
		Excavation and Soil Washing	Contaminants in soil are desorbed by using a solution of leaching agent, surfactant, pH-adjustment, or chelating agent to help remove the contaminants and fine materials on which the contaminants absorbed.	Will address the remedial objectives by removing the contaminants from the soil .	Complex process and produce a large quantity of process water that requires treatment. Acid reagent may be used to remove lead from soil, which increase the health and safety concern during the implementation.	High	No, due to complex implementation and cost
		Excavation and Thermal Treatment	Heat is applied to the excavated soil to increase the volatility of the contaminants. An off-gas treatment will be used to treat the volatilized PAHs and lead. *Ex situ* thermal treatment technologies include hot gas decontamination, incineration, thermal desorption, and vitrification, which is a high-temperature treatment to immobilize contaminants by incorporating them in the vitrified end product.	Will destroy the contaminants (i.e., lead and PAHs), so it will address the remedial objectives.	Not readily implementable, treatability studies required; significant materials handling; specialized equipment and operators; extended construction/ treatment period (6-7 months); viscous nature may require pre-treatment; potential community opposition; potential combination with other technology for residual management; onsite management of residuals will need institutional controls.	High	No, due to complex implementation and cost
		Landfarming	Landfarming is used for the biological treatment of contaminated soil. It consists of spreading excavated contaminated soil either directly on the ground or on a membrane with an upper protective layer to prevent contaminants from migrating to the soil underneath and to the groundwater. Mixing or tilling of the contaminated soil is normally required to blend nutrients/amendments, and distribute moisture to promote biodegradation of the contaminants. Periodical watering is also required to provide optimal condition for microbial activities.	Landfarming is typically applicable to nonvolatile and semi-volatile compounds. Biodegradation of PAHs becomes more difficult as the number of aromatic rings increase. Therefore landfarming typically is not considered to be effective for treating PAHs that contain more than four rings, i.e., benzo(a)pyrene. It is not certain with currently available data if landfarming will be effective for treating lead in soil.	Implementable, however it may take a long period of time depending on biodegradation process in the soil.	Low	No due to ineffectiveness for PAHs with more aromatic rings and lead
	In Situ Treatment	*In Situ* Stabilization/Solidification	Contaminated soil is mixing in place with reagents to form a solid with certain strength and low permeability to immobilize contaminants or reduce contaminants to a less toxic form. Reagents may include Portland cement, lime, fly ash, organoclay, activated carbon, and bentonite.	May stabilize both organic and metal contaminants. Will need institutional controls to protect the treated soil from excavation, drilling, and other earthmoving activities. Institutional controls are required to protect the treated soil. However, the soil contamination is relatively shallow therefore, *in situ* stabilization is not cost effective.	Implementable with commercially available equipment; treatability study is required to determine reagent dosing; may take longer time to treat.	High	No due to high cost
		Phytoremediation	Plants are used to remove, transfer, stabilize and destroy contaminants in soil. Biodegradation takes place in the soil immediately surrounding plant roots; plant roots can also accumulate and stabilize contaminants in the soil.	Effectiveness of phytoremediation can be seasonal; in some cases it is limited to shallow soil. It is uncertain if the contaminant concentrations are tolerant or toxic to plants.	Implementable	Low	No, due to uncertainty of effectiveness

NOTE:
PAH = Polycyclic aromatic hydrocarbon

Table 3. General Response Actions and Potential Applicable Technologies - Groundwater

General Response Action	Remedial Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Potential for Retain for Further Evaluation
No Further Action	None	None	No further actions to address contaminated groundwater.	Will not address the remedial objectives	None	None	Yes as baseline for evaluation process
Institutional Controls	Access and Use Restrictions	Groundwater Use Control	Restriction on groundwater use by implementing a deed notice or covenant restriction for the properties in the contaminated areas.	Will prevent receptors' direct exposure to the contaminants; therefore it will address relevant remedial objectives. Currently there are private wells at the site which are impacted by arsenic and manganese.	Implementable, however depending on property owners' consensus.	Low	Yes
Monitoring	Monitored Natural Attenuation (MNA)	Monitoring	Groundwater monitoring to record site conditions and contamination.	Will be effective if the groundwater has a capacity to attenuate naturally itself. Additional data is required to evaluate the MNA potential.	Implementable	Low	Yes
Containment	Vertical Barriers	Slurry Wall	Trench downgradient of contaminated area excavated and filled with a bentonite slurry which is used for wall stabilization during trench excavation. A soil-bentonite mix is then placed into the trench, displacing the slurry to create a cutoff wall. The wall provides a barrier with low permeability to protect downgradient surface water.	Will not remove or treat the contaminants, although it will prevent contaminants from migrating offsite. It is typically combined with other treatment technologies to address remedial objectives. Compared with a recovery technology it is not effective.	Implementable	Low to Medium	No due to ineffectiveness without other treatment system.
Removal	Removal or Extraction	Pump and Treat	Conventional ground water extraction involves pumping from vertical wells or a recovery trench. Water is treated with various processes including chemical treatment, pH adjustment, flocculation, precipitation, and multimedia filtration.	May need multiple treatment systems or units to treat both arsenic and organic contaminants therefore, the process can be complex.	Implementable, but the process may be complex and operation and maintenance may require highly skilled workers.	Moderate to High	No due to complexity of the treatment
Treatment	In situ Biological Treatment	Enhanced Aerobic Bioremediation	Injection of substrate containing nutrients (i.e., nitrate) and electron acceptors to enhance aerobic biodegradation of organic contaminants (i.e., benzene, ethylbenzene, and naphthalene). During the process, iron and manganese oxides can be generated, which would adsorb arsenic to its adsorbed form.	Effective for organics and will address the remedial objectives; By products, iron and manganese oxides may promote arsenic precipitation.	Implementable, and may require multiple injection events throughout the remedial action period.	Low	Yes
	In situ Physical, Chemical Treatment	In situ chemical oxidation (ISCO)	Injection of oxidizing agents (Fenton's reagent, permanganate, ozone) to promote abiotic *in situ* destruction of the organic compounds.	Will address the remedial objectives, may be effective for the COCs. Under oxidized condition, oxidation of iron and manganese will promote precipitation of metals including arsenic.	Implementable and require a bench scale testing to determine the dosing of oxidants. Chemical injection may adversely impact the nearby water wells, causing health risks.	Moderate to High. High total organic matter in the soil may cause a higher oxidant dosing and make ISCO less cost effective.	No due to potential impact to water wells nearby by the chemical injection
		Air Sparging	Air is injected into saturated matrices to remove contaminants through volatilization. Soil vapor extraction (SVE) may be required to capture the offgas. Applicable for organics in the groundwater at the site.	Will address the remedial objectives by transferring the dissolved phase contaminants to vapor which is collected and treated. Applicable for organic contaminants in the groundwater but not for arsenic. Air sparging may promote oxidation of iron and manganese, which may facilitate arsenic precipitation.	Implementable for organic contaminants for the site. It requires long term operations and maintenance.	Medium	No due to uncertainty on arsenic

Table 3. General Response Actions and Potential Applicable Technologies - Groundwater

General Response Action	Remedial Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Potential for Retain for Further Evaluation
	In situ Physical, Chemical Treatment (continued)	Thermal Treatment	Electrical resistive heating (ERH) - A thermal remediation technology which involves installation of electrodes and application of high voltage electrical power to cause boiling of volatile compounds in groundwater. Volatilized compounds are removed by SVE, treated, and discharged. Thermal conduction heating - Also referred to as *In Situ* Thermal Desorption (ISTD). It involves heating the soil *in situ* by conduction/convection, using heaters installed at relatively close spacing. Although it can be more expensive, it is capable of producing much higher temperatures than ERH and is generally considered a more "aggressive" thermal technology than ERH. Steam injection - Injection of hot air and steam to boil off contaminants.	Will address the remedial objectives for organic volatile contaminants in the groundwater at the site, but not for arsenic.	While implementable, it would require a lot of energy.	High	No due to high cost and not addressing arsenic.

NOTES:

COC = Contaminant of concern
ERH = Electrical resistive heating
ISCO = *In situ* chemical oxidation
ISTD = *In Situ* Thermal Desorption
MNA = Monitored natural attenuation
SVE = Soil vapor extraction

Attachment 1

Development of Preliminary Remediation Goals Based on Ecological Risk Assessment for the Wilcox Oil Company Superfund Site

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301 Metro Center Bvld, Suite 102
Warwick, Rhode Island 02886
Telephone: 401-736-3400
www.eaest.com

15 April 2020

TECHNICAL MEMORANDUM

TO: Katrina Higgins-Coltrain, EPA Region 6

FROM: Melissa Beauchemin, Ecological Risk Assessor

SUBJECT: Development of Preliminary Remediation Goals for the Wilcox Oil Company Superfund Site, Bristow, Creek County, Oklahoma

The following memorandum discusses the derivation of Preliminary Remediation Goals (PRGs) for the Wilcox Oil Company Superfund Site.

1. SLERA RESULTS

A SLERA was conducted in September 2019 following Steps 1 and 2 of EPA's Ecological Risk Assessment Guidance (EPA 1997, 1998). The SLERA used conservative assumptions, including conservative toxicity reference values (TRVs) and input parameters for food web models (e.g., 100% site use, 100% earthworm ingestion, etc.). These steps also assumed maximum exposure scenarios (e.g., maximum ingestion rates and exposure point concentrations [EPCs]). Modifications were conducted as part of Step 3 of the ERA process that used more realistic EPCs (i.e., 95UCL) and incorporated lowest effect level TRVs. Despite the modifications, the SLERA identified potential risks (based on HQs greater than 1) for the following receptors from the following COPECs, per Table 8-1 in the SLERA:

Area	Receptor	COPEC
Wilcox and Lorraine Process Area	Plants	Chromium Copper Lead Vanadium Zinc
	Soil Invertebrates	Chromium Chromium VI Copper Mercury Zinc Carbazole Isopropylbenzene Xylenes
	Insectivorous Mammals	Lead
	Insectivorous Birds	Lead Vanadium
	Herbivorous Birds	Copper Lead

Area	Receptor	COPEC
Tank Farm and Loading Dock Area	Plants	Chromium Manganese Vanadium
	Soil Invertebrates	Chromium Isopropylbenzene
	Insectivorous Birds	Lead Vanadium
Ponds	Aquatic Organisms (SW)	Cadmium Lead Benzo(a)pyrene
Streams	Benthic Invertebrates (SED)	Total PAHs
	Aquatic Organisms (SW)	Manganese

2. SLERA REFINEMENT – LOWER TROPHIC LEVEL ORGANISMS

The following section discusses COPECs for lower trophic level receptors, specifically plants and soil invertebrates that had SLERA HQs greater than 1.

2.1 Total PAHs

Concentrations of Total PAHs in sediment, when compared to the probable effects level (PEL) of 16.8 mg/kg (Swartz 1999) instead of threshold effects level (TEL) of 1.68 mg/kg used in the SLERA, indicates no potential risk to benthic organisms from total PAHs in stream sediments.

2.2 Carbazole, Isopropylbenzene, and Xylenes

Carbazole, isopropylbenzene, and xylenes were sporadically detected in soils at the site. No direct toxicological studies have been published related to these compounds, and the Region 4 soil screening values (EPA 2018) used to identify COPECs were generated from theoretical structure-activity relations (SAR) using the EPA ECOSAR program to generate water values which may result in toxicity to aquatic organisms. The assumption was made that soil invertebrates are equivalent to sediment invertebrates so that partitioning of the chemicals to organic carbon (assuming 1% organic carbon) was used to generate the risk screening values of 0.07, 0.04, and 0.1 mg/kg for carbazole, isopropylbenzene, and total xylenes respectively. Because of infrequent detection, volatile nature of the chemicals, absence of direct toxicological studies, and the unsubstantiated theoretical nature of the soil screening values, it is not expected that either COPECs would result in unacceptable risk to populations of soil invertebrates, and no PRGs have been derived.

2.3 Metals

Where potential risks exist for multiple endpoints (e.g., lower and upper-trophic level organisms), PRGs for metals are unlikely to be based upon lower-trophic level receptors such as plant and soil invertebrates, but rather to upper-trophic level wildlife instead. There is a paucity of toxicological data in the literature for soil invertebrates and plants and soil screening numbers are generally developed to be extremely conservative. The purpose of screening values such as EcoSSLs is to provide a conservative prediction of potential risk so that areas that may present potential risk are not overlooked. This is different than soil clean-up levels or PRGs which are designed for risk management and consider more realistic and site-specific exposure and toxicity scenarios.

Sporadic elevations of concentrations of metals in soil would not necessarily be toxic to entire populations of plants and/or invertebrates. In fact, many plants are tolerant of high concentrations of metals and will accumulate significant concentrations of metals without demonstrating any adverse effects. Because of plants' ability to accumulate concentrations of metals, they are often used for phytoremediation.

Efroymson et al. (1997a) notes that four plant studies showed no adverse effects to plants with lead concentrations in soil of at least 100 mg/kg and even up to 500 mg/kg of lead. In several instances, effects were not observed until lead concentrations in soil were 500 to 1,000 mg/kg. A recent phytotoxicity study by Cheyns et al. (2012) revealed no impacts to tomato and barley plants until lead concentrations in soil reached 1,600 mg/kg for tomatoes and 1,900 mg/kg for barley, at which point growth impacts were observed.

Copper and manganese are essential nutrients in plants and important in oxidation, photosynthesis, and protein and carbohydrate metabolism. Copper deficiency is demonstrated by wilting leaves, melanism, and white twisted tips (EPA 2007a). Manganese deficient plants exhibit decreased growth, interveinal chlorosis, necrotic spots on leaves, and browning of roots (EPA 2007b).

Zinc EcoSSLs have been derived for terrestrial plants and soil invertebrates. The EcoSSL of 160 mg/kg for terrestrial plants was derived based on the geometric mean of the maximum acceptable toxicant concentrations (MATC) for three species under different test conditions. The EcoSSL of 120 mg/kg for soil invertebrates is the geometric mean of the effect concentration for 10 percent of the test population (EC_{10}) and MATC values for at least three test species under different test conditions (EPA 2007d). These values are considered PRGs for the site. However, it should also be noted there is little vegetation present in the process areas where the highest concentrations are located.

Due to the lack of adequate toxicity studies, there are no EcoSSLs for chromium or vanadium for soil invertebrates or plants. There are also no EcoSSL values for mercury. Efroymson et al. (1997a) cautions that their plant "benchmarks are to serve primarily for contaminant screening."

Availability of contaminants for uptake by earthworms is controlled by soil characteristics such as grain size, pH, organic carbon content, and moisture content (Efroymson et al. 1997b). Efroymson et al. 1997b cautions that their soil invertebrate "benchmarks are appropriate for contaminant screening purposes only."

Except for zinc PRGs for plants and invertebrates discussed above, PRGs for metals will be based upon potential risks to upper-trophic level receptors (i.e., birds and mammals) which may consume plants and invertebrates. Cleanup levels based on these wildlife species are likely to be protective of populations of lower trophic organisms as well. As such, the food web models were revised for copper, lead, and vanadium in the next section.

3. FOOD WEB MODEL REFINEMENT – UPPER TROPHIC LEVEL ORGANISMS

As part of the SLERA refinement, food web models can be modified to reflect more realistic and site-specific input parameters. For instance, in the SLERA, to be conservative, the robin was assumed to ingest 100% earthworms; however, robins actually eat a mixed diet that includes both fruits and insects. EPA (1993) indicates that in the central U.S. robins ingest approximately 50% plants and 50% invertebrates. In addition, robins are migratory and will likely reside in the area for only eight months of the year.

The SLERA also assumed the shrew has a soil ingestion rate of 13% based on Sample and Suter (1994). More recent estimates of soil ingestion for the shrew based on EPA's EcoSSL documents (EPA 2007c) indicate that their soil ingestion rate is only approximately 3%. Furthermore, EPA (1993) indicates that shrews also ingest some plant tissue (approximately 17% of their diet) as well as mammals (approximately 5% of their diet). As such, the dietary composition for the shrew was updated.

3.1 Bioaccumulation

Over the past decade, much research has focused on the bioavailability of metals, especially in terms of risk. Only the bioavailable component (species) of metals is capable of uptake by a receptor organism, and therefore, only that portion is capable of eliciting adverse effects. The bioavailability of metals in soil is influenced by the species (forms) present, particle size, organic carbon content, and whether minerals have been encapsulated or coated by other mineral phases. These factors can all influence metal bioavailability, often reducing it to less than 100% (Kaufman et al. 2007).

Bioaccumulation factors (BAFs) used in the food web models for plants and earthworms have been updated in the EcoSSL guidance documents (EPA 2007c) as shown below:

COPEC	Plant BAF	Invertebrate BAF
Copper	$\ln(C_{plant}) = (0.669+0.394*\ln(C_{soil}))$	$C_{worm} = C_{soil}$ x 0.515
Lead	$\ln(C_{plant})=(-1.328+0.561*\ln(C_{soil}))$	$\ln(C_{worm}) = (-0.218+0.807*\ln(C_{soil}))$
Vanadium	$C_{plant} = C_{soil}$ x 0.00485	$C_{worm} = C_{soil}$ x 0.042

3.2 Bioaccessibility

In order to pose a risk to an organism, ingested contaminants must be "bioaccessible," meaning they must be able to enter the gastrointestinal tract of the organism and be absorbed into the bloodstream. The quantity of bioaccessible metal available to an organism can be analyzed in the laboratory via *in vitro* methods. Using a synthetic gastric solution consisting of various acids, laboratories are able to distinguish between organic (bioavailable) and inorganic (non-bioavailable) forms of metals, by the quantity of metal extracted or "digested" from the sample. Suedel et al. (2006) showed that the majority of lead in soil at a former refinery was in its inorganic form, with bioaccessibility percentages ranging from 8 to 78%. Incorporating the bioavailability/bioaccessibility factor into the food web models for the ecological risk assessment substantially reduced risk estimates (Suedel et al. 2006).

Kaufman et al. (2007) conducted bioaccessibility models for mammals (eastern cottontail and short-tailed shrew) and birds (American robin) to investigate the proportion of lead mobilized into the digestive juices (i.e., the bioaccessible fraction) from soil, earthworms, and vegetation collected at a rifle and pistol range in Canada. Total lead concentrations averaged 5,044 mg/kg in surface soil, 727 mg/kg in earthworm tissue, and 2,945 mg/kg in unwashed vegetation. For mammalian gastric models, the bioaccessible fraction of lead in soils was 66%, in earthworm tissue it was 77%, and in unwashed vegetation the bioaccessible fraction was 50%. For the avian gastric model, the bioaccessible fraction of lead in soil was 53%, and in earthworm tissue it was 73%.

Kaufman et al. (2007) demonstrated that the incorporation of soil and food web intermediate bioaccessibility data into standard ecological risk calculations results in lower risk estimates for all receptors. Hazard quotients did not exceed 1 for the American robin until soil lead concentrations reached 1,000 mg/kg. The inclusion of bioaccessibility information during ecological risk assessment provided a more realistic estimate of contaminant exposure and is a valuable tool for use in management of contaminated sites. Using only total metals concentrations can lead to an overestimation of risk and the potential for unwarranted and costly site remediation (Kaufman et al. 2007).

As such, the food web models were modified to incorporate a bioaccessibility factor as follows:

Receptor	Media Ingested	Bioaccessibility Factor (B)
Robin	Soil	53%
	Earthworms	73%
	Plants	100%[a]
Shrew	Soil	66%
	Earthworms	77%
	Plants	50%
Sparrow	Soil	53%
	Plants	100%[a]

a. No value identified by Kaufman et al. 2007 so plants assumed to contain lead that is 100% bioaccessibile.

3.3 TRV Refinement

For the development of avian TRVs, the EcoSSL documents for lead (EPA 2005a) and vanadium (EPA 2005b) present a large range of NOAEL and LOAEL TRVs, many of which are based on chickens. Because chickens are bred for agriculture, they have unnaturally high growth and reproduction rates. Furthermore, chickens do not ingest earthworms and should not be used as a surrogate for insectivorous birds. Many of the studies use gavage methods as the route of exposure in the study. This forced feeding causes animals to have much higher ingestion rates than normal when foraging on their own.

The toxicity dataset used in the EcoSSL documents to identify TRVs includes studies with medium- or low-level confidence. Studies ranked with a Data Evaluation Score of 80 to 100 have a higher degree of confidence than studies ranked in the 60s (low confidence) or 70s (medium confidence).

3.3.1 Lead

EPA's Eco SSL Document for Lead (EPA 2005a) provides a range of avian TRVs that spans up to six orders of magnitude. NOAEL TRVs based on survival, growth, or reproduction range from 0.194 to 196 mg/kg and LOAEL TRVs range from 0.11 to 625 mg/kg. EPA recommends a NOAEL TRV of 1.63 mg/kg-day and a LOAEL of 3.26 mg/kg from the corresponding study. The NOAEL TRV is based on a study (Edens and Garlich 1983) that used chickens which are an inappropriate receptor because, as mentioned above, they are domestic animals with abnormally high reproduction (i.e., egg-laying) and growth rates. The study was based in the laboratory, not in the field, and therefore is not representative of natural conditions. The study was only four weeks long, which is not a sufficiently long study to identify chronic toxicity values.

Sample et al. (1996) calculated a NOAEL TRV of 3.85 mg/kg-day from a study by Pattee (1984). This study evaluated eggshell thickness in American kestrel (wild bird) which is more representative of ecological receptors in their natural habitat with natural reproduction rates. The study was conducted over a period of six months. Because the study was conducted for more than 10 weeks and during a critical lifestage (eggs), the study is considered chronic. EPA (2005) ranked the Pattee (1984) study with the highest evaluation score of all the lead-bird studies (value of 90). The Edens and Garlich (1983) study was ranked only at 79. The NOAEL from the same study as calculated by EPA is 12 mg/kg-day (2005). This discrepancy is likely the result of differing estimated ingestion rates because none was provided in the study. However, EPA (2005) calculated a geometric mean value of all the NOAELs for avian reproduction and growth to be 10.9 mg/kg-day, which is similar to the NOAEL calculated by EPA (2005) from the Pattee (1984) study (12 mg/kg-day). As such the recommended avian NOAEL for lead is 3.85 mg/kg. Because there was no LOAEL associated with the study, an uncertainty factor of 10 is applied to estimate the corresponding LOAEL of 38.5 mg/kg. These values were incorporated into the back-calculated food web model to identify a protective lead soil concentration for birds.

3.3.2 Vanadium

For vanadium, the avian TRVs selected in the EcoSSL document (EPA 2005b) are extremely low – the NOAEL is 0.344 and the LOAEL is 0.688 mg/kg. The EcoSSL dataset has NOAELs for growth, reproduction, and survival that range from 0.244 to 98.7 mg/kg. LOAELs range from 0.319 to 14.8 mg/kg. Because many of the studies use chickens and do not have data scores with a high level of confidence, EA sought to calculate a more reasonable TRV. Studies with endpoints for survival, growth, and reproduction with data evaluation scores less than 80 were eliminated. Studies that did not have a bounded NOAEL and LOAEL were also eliminated. This left a total of 26 studies. Although all based on chickens, data evaluation scores ranged from 81 to 90 indicating a high degree of confidence in the results of the studies. Resulting NOAELs ranged from 0.244 to 6.37 mg/kg and LOAELs ranged from 0.413 to 14.8 mg/kg. The geometric mean of the NOAELs is 1.24 mg/kg and the geometric mean of the LOAELs is 2.5 mg/kg. These values were incorporated into the back-calculated food web model to identify a protective vanadium soil concentration for birds.

3.4 Results

Using the modified input parameters identified above, the food web models were set up to back-calculate a protective soil concentration for copper, lead, and vanadium (i.e., equivalent to a HQ of 1). This was done using the following equation:

$$PPPPPP = CC_{ssssssss} = \frac{TTPPTT \times BBBB \times HHHH}{SSSSSS \times \{(IIPP_{ssssssss} \times BB_{ssssssss}) + (IIPP_{ffsssff} \times BBBBSS \times ffssdddd \times BB_{ffsssff})\}}$$

%

Where:

PRG = preliminary remediation goal (mg/kg)
C_{soil} = concentration in soil (mg/kg)
TRV = toxicity reference value (mg/kg-bw/day)
BW = body weight (kg)
HQ = hazard quotient (unitless)
SUF = site use factor (unitless)
IR_{soil} = ingestion rate of soil (kg/day)
IR_{food} = ingestion rate of food (kg/day)
BAF = bioaccumulation factor (unitless)
B = bioaccessibility factor (percent)

After the exposure parameters and input values were entered into an Excel spreadsheet and the calculation was considered complete, PRGs were developed using the “What if, Goal seek” data function in Excel. This function sets the cell for the HQ to 1 while changing the soil concentration in the equation. This is conducted for both the NOAEL and LOAEL TRV. Geometric mean-based PRGs are a reasonable balance between no effect and lowest effect toxicity levels (EPA 1999). Therefore, the geometric mean of the two values is selected as the PRG. Attached Tables 1 through 3 present the food web models for robin (insectivorous bird), shrew (insectivorous mammal), and sparrow (herbivorous bird), respectively. The following table summarizes the PRGs:

COPEC	Back-Calculated PRG (mg/kg)	Receptor
Copper	**285**	Herbivorous Bird
Lead	**204**	Insectivorous Mammal
	441	Insectivorous Bird
	907	Herbivorous Bird
Vanadium	**66**	Insectivorous Bird

3.5 Background

Background values are also considered because CERCLA does not cleanup to levels below background (EPA 2002). Two background datasets are available, including a site-specific background upper prediction limit (UPL) that was calculated as part of the SLERA as well as regional (Oklahoma) soil background values from the EcoSSL documents (EPA 2007c). Background values for these constituents are lower than the PRGs, as noted below:

COPEC	UPL (mg/kg)	Regional OK Background (mg/kg)	Final PRG (mg/kg)	Basis
Copper	3.24	15.9	285	Herbivorous bird
Lead	9.19	17.6	204	Insectivorous Mammal
Manganese	505	465	505	UPL
Vanadium	11.17	50	66	Insectivorous Bird
Zinc	14.2	50	120	Soil Invertebrates

Note: The EcoSSL for manganese that is protective of plants is 220 mg/kg which is lower than either background concentration.

3.6 Aquatic Organisms

Potential risks to aquatic organisms in the ponds and streams from elevated concentrations of constituents in the water column are likely to be reduced following removal of contaminated soil in the upland. Because sediment in these areas is not impacted and there is no need for sediment removal, water quality monitoring may be necessary to ensure that water column concentrations decrease following soil removal activities.

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Tables

Tables

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Preliminary Remediation Goals for American robin

LOAEL-based values

	Body Weight (kg)	SUF	Bioaccessibility Plants	Bioaccessibility Inverts	Bioaccessibility Soil	Dietary Composition (%) Plants	Dietary Composition (%) Inverts	Tissue Concentrations (mg/kg) Plants	Tissue Concentrations (mg/kg) Inverts	Food Ingestion Rate (kg/day dw)	Soil Ingestion Rate	Dietary Dose (mg/kg-day)	TRV (mg/kg-d) LOAEL	STCL (mg/kg) LOAEL	HQ
Lead	0.077	0.67	1.00	0.73	0.53	50%	50%	17	314	0.0171	0.0018	38.49	38.5	1627.55	1.00
Vanadium	0.077	0.67	1	1	1	50%	50%	0.452	4	0.0171	0.0018	2.50	2.5	93.09	1.00

NOAEL-based values

	Body Weight (kg)	SUF	Bioaccessibility Plants	Bioaccessibility Inverts	Bioaccessibility Soil	Dietary Composition (%) Plants	Dietary Composition (%) Inverts	Tissue Concentrations (mg/kg) Plants	Tissue Concentrations (mg/kg) Inverts	Food Ingestion Rate (kg/day dw)	Soil Ingestion Rate	Dietary Dose (mg/kg-day)	TRV (mg/kg-d) NOAEL	STCL (mg/kg) NOAEL	HQ
Lead	0.077	0.67	1	0.73	0.53	50%	50%	4	38	0.0171	0.0018	3.85	3.85	119.59	1.00
Vanadium	0.077	0.67	1	1	1	50%	50%	0.22	2	0.0171	0.0018	1.24	1.24	46.17	1.00

	Geomeans	Bkgd
lead	**441**	18
vanadium	**66**	50

Exposure Parameters

	Body Weight	0.077 kg	
Lead	BAFworm	ln(dry worm conc, mg/kg) = (-0.218+0.807*ln(soil conc))	EcoSSL
Lead	BAFplant	ln(dry plant conc, mg/kg) = (-1.328+0.561*ln(soil conc))	EcoSSL
Vanadium	BAFworm	4.20E-02	EcoSSL
Vanadium	BAFplant	4.85E-03	EcoSSL
Copper	BAFworm	0.515	EcoSSL
Copper	BAFplant	ln(dry plant conc, mg/kg) = (0.669+0.394*ln(soil conc))	EcoSSL

Bird TRVs	NOAEL	LOAEL	Ref
Lead	3.85	38.5	Sample et al. 1996
copper	4.05	12.1	EcoSSL TRVs
Vanadium	1.24	2.5	self-derived TRVs

Mammal TRVs	NOAEL	LOAEL	
Lead	4.7	8.9	EcoSSL

Food Ingestion Rate	0.22	kg dry wt./kg-day	Converted assuming 75% prey moisture (USACHPPM 2004)
Food Ingestion Rate	0.89	kg wet wt./kg-day	EPA 1993
Incidental Soil Ingest	10.50%	% of total mass of diet	Value based on woodcock (Sample and Suter 1994)

Food ingestion	0.0171325	dry weight	kg/d
Food ingestion	0.06853	wet weight	kg/d
soil ingestion	0.0017989	dry	kg/d

SOUTHERN SHORT-TAILED SHREW

Body Weight	0.017213	kg		Plants	17%
Food Ingestion Rate	0.16	kg dry wt./kg-day		Inverts	78%
Food Ingestion Rate	0.62	kg wet wt./kg-day		Mammals	5%
Incidental Soil Ingestion Rate	3.00%	% of total mass of diet			
FIR	0.00275	kg/d			
SIR	8E-05	kg/d			

Preliminary Remediation Goals for Shrew

LOAEL-based values

	Body Weight (kg)	SUF	Bioaccessibility			Dietary Composition (%)			Tissue Concentrations (mg/kg)			Food Ingestion Rate (kg/day dw)	Soil Ingestion Rate (kg/day dw)	Dietary Dose (mg/kg-day)	TRV (mg/kg-d)	STCL (mg/kg)	HQ
			Inverts	Soil	Plants	Inverts	Plants	Mammals	Inverts	Plants	Mammals				LOAEL	LOAEL	
Lead	0.017213	1	0.77	0.66	0.50	78%	17%	5%	81	7	13	0.0028	0.0001	8.90	8.9	301.79	1.00

NOAEL-based values

	Body Weight (kg)	SUF	Bioaccessibility			Dietary Composition (%)			Tissue Concentrations (mg/kg)			Food Ingestion Rate (kg/day dw)	Soil Ingestion Rate (kg/day dw)	Dietary Dose (mg/kg-day)	TRV (mg/kg-d)	STCL (mg/kg)	HQ
			Inverts	Soil	Plants	Inverts	Plants	Mammals	Inverts	Plants	Mammals				NOAEL	NOAEL	
Lead	0.017213	1	0.77	0.66	0.5	78%	17%	5%	43	4	10	0.0028	0.0001	4.70	4.70	138.33	1.00

Geomean **204**

SONG SPARROW

Body Weight	0.032	kg	Sherman and Wasser 2010; average weight of song sparrow
Food Ingestion Rate	0.2141	kg dry wt./kg-day	Calculated using allometric equation for birds from Nagy 2001
Food Ingestion Rate	0.8566	kg wet wt./kg-day	Converted assuming 75% prey moisture (USACHPPM 2004)
Incidental Soil Ingestio	9%	% of total mass of diet	Beyer et al 1994, value for turkey

FIR	0.0068512	kg/d
SIR	0.0006166	kg/d

Preliminary Remediation Goals for Song Sparrow

LOAEL-based values

	Body Weight (kg)	SUF	Bioaccessibility Plants	Bioaccessibility Soil	Dietary Composition (%) Plants	Tissue Concentrations Plants	Food Ingestion Rate (kg/day dw)	Soil Ingestion Rate (kg/day	Dietary Dose (mg/kg-day)	TRV (mg/kg-d) LOAEL	STCL (mg/kg) LOAEL	HQ
Lead	0.032	1	1.0	0.53	100%	25	0.0069	0.0006	38.50	38.5	3250.83	1.00
Copper	0.032	1	1	0.53	100%	25	0.0069	0.0006	12.10	12.1	657.24	1.00

NOAEL-based values

	Body Weight (kg)	SUF	Bioaccessibility Plants	Bioaccessibility Soil	Dietary Composition (%) Plants	Tissue Concentrations Plants	Food Ingestion Rate (kg/day dw)	Soil Ingestion Rate (kg/day	Dietary Dose (mg/kg-day)	TRV (mg/kg-d) NOAEL	STCL (mg/kg) NOAEL	HQ
Lead	0.032	1	1	0.53	100%	6	0.0069	0.0006	3.85	3.85	253.00	1.00
Copper	0.032	1	1	0.53	100%	13	0.0069	0.0006	4.05	4.05	123.54	1.00

	Geomean
Lead	907
Copper	285

Attachment 2

Development of Human Health Risk Based Preliminary Remediation Goals for the Wilcox Oil Company Superfund Site

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405 S. Highway 121, Building C, Suite 100
Lewisville, Texas 75067
Telephone: 972315-3922
www.eaest.com

16 April 2020

TECHNICAL MEMORANDUM

TO: Katrina Higgins-Coltrain, EPA Region 6

FROM: Cynthia Cheatwood, Human Health Risk Assessor / EA Engineering, Science, & Technology, Inc., PBC (EA)

SUBJECT: Development of Human Health Risk Based Preliminary Remediation Goals for the Wilcox Oil Company Superfund Site, Bristow, Creek County, Oklahoma

This technical memorandum discusses the derivation of Preliminary Remediation Goals (PRGs) based on the human health risk assessment (HHRA) for the Wilcox Oil Company Superfund Site.

1. DEVELOPMENT OF PRGS

Risk results from the HHRA were reviewed to determine PRGs for the site. The site-specific PRGs are chemical limits calculated upon toxicity values and site-specific exposure conditions evaluated in the HHRA (EA 2020). As presented in the HHRA, the site was divided into five exposure areas for evaluation due to the sites overall size and configuration. The HHRA determined potential health concerns for selected receptors exposures to lead in soil (Lorraine Process Area and Wilcox Process Area) and shallow groundwater (Wilcox Process Area). For shallow groundwater, potential unacceptable risks were determined for the resident, construction worker, and commercial worker exposure.

Additionally, soil sample results were reviewed to determine if areas of high concentration are present within the five soil exposure areas. Areas of high concentration were determined as concentrations that exceed the residential soil Regional Screening Level (RSL) by two orders of magnitude (i.e., 100 times). The only chemical that exceeded this criterion was benzo(a)pyrene. Therefore, benzo(a)pyrene was also identified as a chemical of concern (COC).

PRGs were determined for each of the chemicals identified as COCs. PRGs were developed for chemicals with cancer risks greater than 10^{-6} and target organ specific Hazard Index (HI) greater than 1. Tables 1 through 3 present the PRGs. The PRGs are for cancer risk levels of 10^{-6}, 10^{-5}, and 10^{-4} or a noncancer hazard of 0.1 and 1. The following equation was used to calculate site-specific PRGs:

For carcinogens:

$$Site\ Specific\ PRG = \frac{EPC}{Risk} \, x \, TR$$

Where,

PRG = Preliminary remediation goal

TR	=	Target carcinogenic risk level (i.e., 10^{-6}, 10^{-5}, 10^{-4})
Risk	=	Chemical-specific cumulative carcinogenic risk calculated in HHRA
EPC	=	Chemical-specific exposure point concentration presented in HHRA

For non-carcinogens:

$$Site\ Specific\ PRG = \frac{EPC}{HQ} \text{x} THQ$$

Where,

PRG	=	Preliminary remediation goal
THQ	=	Target hazard quotient (i.e., 1, 0.1)
HQ	=	Chemical-specific total hazard quotient shown in HHRA
EPC	=	Chemical-specific exposure point concentration presented in HHRA.

2. SELECTION OF PRGS

A brief discussion of the risk-based PRGs is presented below.

2.1 Soil

Lead is classified a probable human carcinogen. However, EPA has not published a slope factor (SF) or inhalation unit risk (IUR) for quantifying carcinogenic risks. Blood lead levels are the indicator of excess lead exposure in humans. In the HHRA, modeled blood level results are compared to the established threshold of no more than 5 percent of the population having a blood-lead of 5, 8, and 10 micrograms (µg) lead per deciliter (dL) or greater. Blood-lead levels were evaluated for residents using the EPA's Integrated Exposure Uptake Biokinetic Model (IEUBK) Lead Model and for workers using the EPA's Recommendations of the Technical Review Workgroup (TRW) for Lead, An Interim Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil. Land use within the five exposure areas at the site vary from residential to commercial/industrial. Zoning does not exist for the area the site is located. As a result, acceptable lead concentrations in soil may vary within an exposure area. To simply this difference in land use across the exposure area, two separate lead PRGs were selected. The EPA RSL for residential soil (400 mg/kg) and industrial soil (800 mg/kg) were selected as PRGs. The selection of the appropriate PRG will depend upon identified land use and remedial feasibility.

For benzo(a)pyrene, the highest concentrations in soil were found just north of the lead additive area in the Wilcox Process Area (sample locations WPA-SB-09, WPA-SB-18 and WPA-SB-20). Based upon the "hot spot" area of benzo(a)pyrene, a PRG of 3 mg/kg is selected. This PRG would result in removal of the polycyclic aromatic hydrocarbon (PAH) "hot spot" and result in risks within the EPA acceptable risk range for both a resident and a worker.

2.2 Groundwater

Potential risks were assessed for groundwater based upon monitoring well results within the perched aquifer. Potential risk concerns for exposure to groundwater within the perched aquifer were determined for all receptor's exposure to groundwater. Due to the low frequency of detection, the exposure point concentration for volatile organic compounds (VOCs) evaluated in the HHRA is the maximum detected concentration. The maximum detected concentration for VOCs were detected within MW-04, within the Wilcox Process Area, and are approximately three orders of magnitude higher than detections in other wells. It is also noted that these VOCs were not detected in the residential groundwater wells. Groundwater risk concerns based upon monitoring well results are centralized within the Wilcox Process Area. Groundwater in this area of the site is not currently used as a tap water source and is also a location of significant soil contamination. As a result, the restoration of groundwater to potential beneficial use is considered the primary objective for the selection of groundwater PRGs. Therefore, risk-based PRGs that correspond to a cancer risk level of 10^{-5} or a noncancer hazard of 1 are presented on the summary table. If an EPA MCL is available for a COC, the MCL is selected as the PRG.

3. REFERENCES

EA Engineering, Science, and Technology, Inc. PBC. 2020. *Final Human Health Risk Assessment, Revision 02, Remedial Investigation / Feasibility Study, Wilcox Oil Company Superfund Site, Bristow, Creek County, Oklahoma*. April

Tables

1	PRG Calculation, Reasonable Maximum Exposure, Wilcox Process Area, Residential, Child and Adult
2	PRG Calculation, Reasonable Maximum Exposure, Wilcox Process Area, Construction Worker
3	PRG Calculation, Reasonable Maximum Exposure, Wilcox Process Area, Commercial / Industrial Worker

Tables

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TABLE 1
PRG CALCULATION
REASONABLE MAXIMUM EXPOSURE
WILCOX OIL COMPANY SUPERFUND SITE - WILCOX PROCESS AREA
BRISTOW, CREEK COUNTY, OKLAHOMA

Location: Wilcox Process Area
Scenario Timeframe: Current/Future
Receptor Population: Resident
Receptor Age: Child and Adult

Medium	Exposure Medium	Exposure Point	Chemical of Concern	Exposure Point Concentration	Carcinogenic Risk				Chemical of Concern	Non-Carcinogenic Hazard Quotient			
					Exposure Routes Total	Preliminary Remediation Goal				Primary Target Organ	Exposure Routes Total	Preliminary Remediation Goal	
						Risk = 10^{-6}	Risk = 10^{-5}	Risk = 10^{-4}				HI = 0.1	HI = 1.0
Soil	Surface Soil	Wilcox Process Area (Child)	**PAHs**						**PAHs**				
			BENZO(A)PYRENE	2.53	1.9E-05	NA	NA	NA	BENZO(A)PYRENE	Developmental System	NA	NA	NA
		Wilcox Process Area (Adult)	**PAHs**						**PAHs**				
			BENZO(A)PYRENE	2.53	2.7E-06	NA	NA	NA	BENZO(A)PYRENE	Developmental System	NA	NA	NA
		Wilcox Process Area (Adult + Child)	**PAHs**										
			BENZO(A)PYRENE	2.53	2.2E-05	0.12	1.2	11.5					
Groundwater	Groundwater	Tap Water (Child)	**Inorganics**						**Inorganics**				
			ARSENIC	0.0198	1.3E-04	NA	NA	NA	ARSENIC	Skin, Cardiovascular	3.3E+00	0.0006	0.006
			CYANIDE	0.0471	NA	NA	NA	NA	CYANIDE	Gastrointestinal System	3.9E+00	0.0012	0.012
			IRON	33.447	NA	NA	NA	NA	IRON	Gastrointestinal System	2.4E+00	1.4	14.0
			PAHs						**PAHs**				
			NAPHTHALENE	0.0592	NA	NA	NA	NA	NAPHTHALENE	Body Weight	2.3E-01	0.03	0.3
			Volatiles						**Volatiles**				
			BENZENE	2.4	6.4E-04	NA	NA	NA	BENZENE	Immune System	3.4E+01	0.007	0.07
			1,2-DICHLOROETHANE	0.0041	1.7E-06	NA	NA	NA	1,2-DICHLOROETHANE	NA	NA		
			ETHYLBENZENE	1.1	7.8E-05	NA	NA	NA	ETHYLBENZENE	Liver, Kidney	8.3E-01	0.13	1.3
		Tap Water (Adult)	**Inorganics**						**Inorganics**				
			ARSENIC	0.0198	2.6E-04	NA	NA	NA	ARSENIC	Skin, Cardiovascular	2.0E+00	0.001	0.01
			CYANIDE	0.0471	NA	NA	NA	NA	CYANIDE	Gastrointestinal System	2.4E+00	0.002	0.02
			PAHs						**PAHs**				
			NAPHTHALENE	0.0592	3.6E-04	NA	NA	NA	NAPHTHALENE	Body Weight	9.6E+00	0.0006	0.006
			Volatiles						**Volatiles**				
			BENZENE	2.4	4.6E-03	NA	NA	NA	BENZENE	Immune System	5.9E+01	0.004	0.04
			1,2-DICHLOROETHANE	0.0041	2.2E-05	NA	NA	NA	1,2-DICHLOROETHANE	NA	3.0E-01	0.001	0.01
			ETHYLBENZENE	1.1	6.5E-04	NA	NA	NA	ETHYLBENZENE	Liver, Kidney	1.0E+00	0.11	1.1
		Tap Water (Adult + Child)	**Inorganics**										
			ARSENIC	0.0198	3.8E-04	0.00005	0.0005	0.0052					
			PAHs										
			NAPHTHALENE	0.0592	3.6E-04	0.00017	0.0017	0.017					
			Volatiles										
			BENZENE	2.4	5.3E-03	0.00046	0.0046	0.046					
			1,2-DICHLOROETHANE	0.0041	2.4E-05	0.00017	0.0017	0.017					
			ETHYLBENZENE	1.1	7.3E-04	0.0015	0.015	0.15					

TABLE 2
PRG CALCULATION
REASONABLE MAXIMUM EXPOSURE
WILCOX OIL COMPANY SUPERFUND SITE - WILCOX PROCESS AREA
BRISTOW, CREEK COUNTY, OKLAHOMA

Location: Wilcox Process Area
Scenario Timeframe: Current/Future
Receptor Population: Construction Worker
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Concern	Exposure Point Concentration	Carcinogenic Risk				Chemical of Concern	Non-Carcinogenic Hazard Quotient			
					Exposure Routes Total	Preliminary Remediation Goal				Primary Target Organ	Exposure Routes Total	Preliminary Remediation Goal	
						Risk = 10^{-6}	Risk = 10^{-5}	Risk = 10^{-4}				HI = 0.1	HI = 1.0
Groundwater	Groundwater	Wilcox Oil	**PAHs**						**PAHs**				
			NAPHTHALENE	0.0592	NA	NA	NA	NA	NAPHTHALENE	Body Weight	3.9E+00	0.0015	0.015
			Volatiles						**Volatiles**				
			BENZENE	2.4	NA	NA	NA	NA	BENZENE	Immune System	2.3E+01	0.010	0.10
			M,P-XYLENE	2.3	NA	NA	NA	NA	M,P-XYLENE	Body Weight, Mortality	5.6E+00	0.041	0.41

TABLE 3
PRG CALCULATION
REASONABLE MAXIMUM EXPOSURE
WILCOX OIL COMPANY SUPERFUND SITE - WILCOX PROCESS AREA
BRISTOW, CREEK COUNTY, OKLAHOMA

Location: Wilcox Process Area
Scenario Timeframe: Current/Future
Receptor Population: Commercial/Industrial Worker
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Concern	Exposure Point Concentration	Exposure Routes Total	Preliminary Remediation Goal Risk = 10^{-6}	Preliminary Remediation Goal Risk = 10^{-5}	Preliminary Remediation Goal Risk = 10^{-4}	Chemical of Concern	Non-Carcinogenic Hazard Quotient: Primary Target Organ	Non-Carcinogenic Hazard Quotient: Exposure Routes Total	Non-Carcinogenic Hazard Quotient: Preliminary Remediation Goal HI = 0.1	Non-Carcinogenic Hazard Quotient: Preliminary Remediation Goal HI = 1.0
Soil	Surface Soil	Wilcox Process	**PAHs**						**PAHs**				
			BENZO(A)PYRENE	2.53	8.5E-07	3.0	30	299	BENZO(A)PYRENE	Developmental System	NA	NA	NA
Groundwater	Groundwater	Tap Water	**Inorganics**						**Inorganics**				
			ARSENIC	0.0198	1.1E-04	0.0002	0.002	0.02	ARSENIC	Skin, Cardiovascular	NA	NA	NA
			Volatiles						**Volatiles**				
			BENZENE	2.4	6.3E-04	0.004	0.04	0.4	BENZENE	Immune System	8.0E+00	0.03	0.3